FORCES SET UP IN A CONDUCTOR BY A CURRENT "PINCH EFFECT"

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by a current pinch effect

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CONDUCTOR BY A CURRENT

"PINCH EFFECT"

A THESIS

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ELECTRICAL ENGINEERING

Approved
[illegible]

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[illegible] object of [illegible] is thesis was:- "To find the [illegible] relation [illegible] distance from the center of a conductor has on the so called "pinch effect" [illegible] it". This however, I was unable to find out experimentally. In spite of [illegible] very valuable help which I received from Mr. Wilcox (and I [illegible] him very much for that), still I could not get [illegible] apparatus which at least could show that the pinch effect is different at different parts of the conductor, even if I could not measure such difference. I [illegible] experiment which was suggested by Mr. [illegible], [illegible] is [illegible] value. There are very little or no [illegible] from which to [illegible] ideas [illegible] on this subject. In fact, the only [illegible] is an article [illegible] in the "Physical Review" of [illegible]. 1907 - [illegible], [illegible] Dr. [illegible]. This however, is an entirely theoretical article, [illegible] experiments which [illegible] pinch effect exists, [illegible] it does not give any idea as to how to [illegible] out to prove the relation of the pinch effect to the distance from the center of the conductor. Before I go any further, however, I think it best to say [illegible] about [illegible] "pinch effect".

[illegible]

If A and B (Fig.-I) are two conductors each [illegible] current in the direction indicated by the arrows, fields will [illegible]

$$I_r = \frac{2Ir}{R^2}$$

$$\frac{I}{A} = \frac{di}{da}$$

$$da = \pi(r + dr)^2 - \pi r^2 = 2\pi r dr$$

[illegible] $\overline{dr}^2$

As $\pi R^2 =$ [illegible]

$$di = \frac{2Ir\,dr}{R^2}$$

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] of

[illegible]

[illegible]

$$dF = \rho\, di\, T_r$$

[illegible] a [illegible].

$$dg = \frac{dF}{2\pi r \rho} = \frac{2I^2 r\,dr}{\pi R^4}$$

[illegible]

[illegible]

$$g = \frac{2I^2}{\pi R^4}\int_r^R r\,dr = \frac{I^2}{\pi R^4}\left(R^2 - r^2\right)$$

If we [illegible] I^1 [illegible]

$$I^2 = \pi^2 I'^2 R^4$$

substi[illegible]

$$g = \pi I'^2 (R^2 - r^2)$$

[illegible]

$$g = \pi I'^2 R^2$$

[illegible]

If [illegible]

[illegible] equals [illegible]

which is [illegible].

[illegible]

$$g = \pi I'^2 \left(R^2 + \tfrac{1}{4} R^2\right) = \tfrac{3}{4} \pi I'^2 R^2$$

[illegible]

... force ... [illegible]

$$P = 2g\,\ell r = 2\pi \ell r I'^2 (R^2 + r^2)$$

If ... consider ... [illegible]

[illegible]

$$F = 2 i i_1 \frac{\ell}{r}$$

... force, ... [illegible]

[illegible]

radius ... [illegible]

[illegible]

$$i = \frac{r^2}{R^2} I$$

... if $2\pi r\,dr$ is ... cross ... [illegible]

$$di = \frac{2 r\,dr\,I}{R^2}$$

df is ... [illegible]

[illegible]

$$dF = \frac{2 i\,di'\,\ell}{r} = \frac{4 \ell I^2 r^2\,dr}{R^4}$$

[illegible]

$$dg = \frac{dF}{2\pi r \ell} = \frac{2 I^2 r\,dr}{\pi R^4}$$

[illegible]

$$g = \frac{2 I^2}{\pi R^4} \int_r^R r\,dr = \frac{I^2 (R^2 - r^2)}{\pi R^4}$$

$$P = 2 \ell I^2 r \,\frac{(R^2 - r^2)}{R^4}$$

... expression ... [illegible]

$$F = \frac{2\,i_1 i' \ell}{r}$$

$$F = \frac{2\,i' i_1}{r}$$

$$i' = \frac{r^2}{R^2} I$$

substituting

$$F = \frac{2\,r\,i_1 I}{R^2}$$

If I_1 ...

$$F_t = 2\pi I_1 r$$

IV

... is ... as ...

... is ...

nobody ...

as expressed ...

... is ...

IV-

"Mercury interrupter", ...

... two square ...

... coils.

... coils,

reach ...

was broken ...

the depression would take place [illegible] circuit [illegible] would [illegible].

IV-b

Another ex[illegible] was [illegible] devised and [illegible] [illegible]ratus [illegible] in Fig. [illegible] was [illegible]. This consisted of [illegible] box [illegible] compart-ments, [illegible] by a [illegible]. On [illegible] side of [illegible] box [illegible] ca[illegible] as to be able to see [illegible] outside [illegible] level of [illegible] liquid; electrodes [illegible] fastened at each end of the box. A liquid alloy of [illegible] was [illegible] in this box to a depth of two inches, [illegible] was filled with kerosene. When a current of [illegible] 130 [illegible]. was passed a [illegible] of 1-[illegible]" was noticed. In this experiment it was found [illegible] current [illegible] given constant depression.

IV-c

By means of the apparatus in Fig. [illegible] not only [illegible] able to prove the fact that the [illegible]inch effect existed but [illegible] actually measured the pressure at the center of the conductor.

As it can be seen from Fig. [illegible] the apparatus consists of two tubes made of non-conducting material, the electrodes being attached to the inside tube and the two tubes being interconnected by the holes [illegible]. [illegible] is a [illegible] so to further reduce the cross section of the inner tube. [illegible] there is a hole [illegible]. When no current was passed [illegible], the mercury was at a certain level, but when a current was passed the mercury rose in the hole [illegible], so that with 1[illegible] am[illegible]. a [illegible] stream was obtained. When [illegible] was fitted [illegible], it was found that the mercury rose [illegible] of an inch.

In order to increase this effect they fitted in place of [illegible] made of iron and fiber as seen in Fig. [illegible]. This disk consists of [illegible] fiber like [illegible] and a piece of iron, [illegible] slot was cut [illegible] this disk and the whole thing was fitted in the tube so that [illegible] of the slot [illegible] with one of the holes [illegible]. (Fig. [illegible]) [illegible] intensity of [illegible] field [illegible].

space of the narrow slot should [illegible] iron; [illegible] same time the [illegible] mercury will [illegible] urged [illegible] increased force toward [illegible] axis [illegible] hydrostatic pressure at the axis. [illegible] it is so [illegible] with [illegible] as [illegible] before [illegible].

[illegible] mercury [illegible] built on the same principle [illegible]. The only difference is [illegible] series as shown in the Fig. 7. [illegible], the [illegible] middle of cup A is [illegible] cup B, [illegible] least, and [illegible] same [illegible] cup C, etc. Now a very little current will cause a [illegible] rise of the mercury. [illegible] however, instead of taking mercury, which is very heavy, rise in the glass tube [illegible], [illegible] oil or [illegible], which is much lighter and [illegible] it takes less pressure to [illegible].

V.

Now [illegible] question arises. Is it possible to measure the [illegible] of the rise to the distance from the center of the [illegible]? Of course it is easy to calculate [illegible], but can we actually measure it experimentally? At first I [illegible] scheme shown in Fig. 8, [illegible] is [illegible] of insulating material with [illegible] so [illegible] glass tubes. [illegible] current, I [illegible] at first that the liquid would rise most in the center, [illegible] according [illegible] pressure is [illegible] maximum at the center and zero at the sides. [illegible] should [illegible] is [illegible] work, because of the fact [illegible] liquid [illegible] equal at all points (according to the well known law of hydraulics) and therefore if the liquid rose at all, it would rise equally at all points. [illegible] this plan.

Then Mr. Teddibo suggested that I take a cylinder [illegible] of large corss section and drill holes axially through it. Will these holes [illegible] and in passing the current through the conductor [illegible] should rise to different heights, if the holes were drilled at different distances from the center. I thought this apparatus would not work for several reasons, [illegible] nevertheless did build it [illegible].

VI

I took (Fig. 10) a conductor of [illegible] in [illegible] I drove four or five axial holes all at different distances from the center of the conductor. Then I drove other holes radially to the conductor and connected the axial holes to the outside surface of the conductor. Now I closely [illegible] a piece of glass to the top of the axial holes, and to the radial holes I fitted a glass tube bent at right angle. In this manner I built a U tube the [illegible] of which was the axial hole in the conductor. First I put mercury in these tubes and passed a current. I was not able to notice any rise with a current of 2000 amp. going through it. Then I thought that the mercury [illegible] too heavy for sush an experiment, so I tried the same experiment with the same current, first with salt water and then with a solution of copper sulphate, and still no results.

VII

As I said before, there are several reasons why this scheme would not work. First of all it is out of the question that the pinch effect in [illegible] itself would cause the liquid to rise, because if there is such a thing as a pinch effect, it is not [illegible] to make the [illegible] contract or expand, but it is taken in strains in the iron itself, so that the cross section of the hole will not change. But just for the sake of argument let us suppose for a minute that the liquid is actually pinched. I tried this experiment first with both sides of the U tube open to the atmosphere. [illegible] is no pinch effect the liquid is at the same level in [illegible]

only pressure in then is the atmospheric pressure (14.7 lbs./sq. in.) [illegible] the same in the two branches and therefore its summation is zero. [illegible] current; the pinch effect pushes the liquid apart. P[illegible] it does so a vacuum must be created in the U tube in order to allow the liquid [illegible], but if this vacuum is created then the atmospheric pressure will [illegible] come into play and keep the liquid at the same level, [illegible] of [illegible] strong as the atmospheric pressure. Now I [illegible] metallic [illegible] and I passed a current. Now again the liquid will be pushed toward the [illegible] branch and again the tendency to create vacuum, with [illegible] will be no rise of the liquid due to the atmospheric pressure. [illegible] that the pinch effect in the iron itself will not cause the liquid to rise.

The next thing to do is to think that the pinch effect in the liquid itself might cause it to rise, this however runs us into other difficulties. Of course I know that I had about 200 amps. [illegible] the piece of iron, [illegible] how was the current distributed in that mass of iron? [illegible] theoretically how the field was distributed and hence the pinch effect, but what part of the current for instance passed at half the distance between the center and the outside surface of the iron. And what is more to the point, does as much current pass through the liquid as passes through the iron immediately surrounding the liquid? We can see at once that, that current passing through the liquid is much less than that passing through the iron. Because the conductivity of the iron is much higher. [illegible] if the conductivity of the iron is higher its impedance (A.C. [illegible] used) is also higher while that of the liquid is practically zero, but even so, still the current passing through the liquid is much less than 200 amp. According to Mr. Northrup's article [illegible] pinch effect is noticeable only at high currents [illegible] reason why we were unable to get results in this experiment was [illegible] current [illegible]

the liquid. Then Mr. Wilcox suggested that I build the apparatus shown in Fig. 6 in the block of iron, as shown in Fig. 11, at different distances from the center of the conductor. Have the mercury up to a certain height in the tube A and then pass a current. Of course it is certain that the mercury would rise in this case, if the current is high enough, but then we would be getting away from our original proposition viz: "To find the relation of the pinch effect to the distance from the center of a conductor. In this case we would be proving that the pinch effect is different with different currents, because we would not be measuring the pinch effect in the conductor itself, but the pinch effect in a column of mercury put at certain distance from the center of the conductor. In which case we might just as well build an apparatus as we have in Fig. 6 and just pass different currents through it without building it in a mass of iron as was suggested.

VIII

I am sorry I am unable to show better results than I have actually obtained in this work, I must point out however that I did the best I could if we consider that although I have had plenty of good, hard experimental work in the school still I had never before done research work. To make things still worse, very little or no work has been done on this line before and therefore there are no references to be found, which might give at least some suggestions of how to go at this work. Before I close however I must again thank Mr. Wilcox for his most valuable help which he offered.

FINIS.